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My invention relates to SOLDER. It has to do primarily with the provision of a solder especially adapted for the soldering of copper, although it is not necessarily limited thereto.

In the prior art, various types of solder have been provided. Predominant among these are the various commercial solders formed usually from alloys of tin and lead. Solders of this type, though quite useful in many spheres, are possessed of certain possible drawbacks when applied to such service as the soldering of copper roofs.

Thus, it is alleged by some that the ordinary lead-tin solder tends to form compounds with the copper which, in the presence of an electrolyte such as water containing absorbed gases or alkali metal salts, may set up a difference in electrolytic potential thought to result in galvanic corrosion of the copper. This type of corrosion is said to be responsible, at times, for what is known as "pitting," "pinholing" and "line corrosion" of the copper adjacent to the soldered surface. Conditions favorable to the production and acceleration of corrosion of this type is alleged to be present, more particularly, on copper roofing or other installations of a similar class, where water has a tendency to lie and form a pool or where there is capillary attraction.

Some effort has been made to develop solders for use with copper, particularly in connection with motors. However, the described type of corrosion alleged to occur in copper roofs and the like does not ordinarily occur in motors. Moreover, the said solders especially designed for motors and the like apparently possess such high melting points that blow-torches

must ordinarily be used to effect application thereof, with a consequent tendency towards burning or drossing and when an attempt is made to use soldering irons there is danger of dirty irons and decreased speed of work, resulting in impracticability of using solders of this kind.

One of the objects of this invention is to provide a solder which will obviate any tendency that may exist towards galvanic corrosion.

Another object of this invention is to provide a solder of the type indicated that will be particularly suitable in connection with the soldering of copper but which will have a melting point sufficiently low to render unnecessary the use of blow-torches or the like during the soldering operations.

Other objects of this invention will appear as this description progresses.

My invention contemplates the production of a solder in the form of an alloy mainly consisting of lead. Preferably alloyed with the lead is cadmium in considerably lesser amount and a small quantity of zinc. Under certain circumstances I may find it desirable to substitute bismuth for the cadmium of the alloy or to use it in combination therewith.

More specifically, my alloy preferably comprises lead alloyed with cadmium or bismuth or both in an amount up to 20% and zinc in an amount up to 0.75%. For example, alloys of the following composition have been made by me and have been found to satisfactorily attain the desired results:

		<u>No.1</u>	<u>No.2</u>	<u>No.3</u>
Lead	=	85.40%	82.55%	83.50%
Cadmium	=	14.30	17.45	6.00
Bismuth	=	None	None	10.00
Zinc	=	<u>0.30</u>	<u>None</u>	<u>0.50</u>
		100.00%	100.00%	100.00%

The relation which the elements preferably used in my solder and other solders bear to copper in the presence of an electrolyte is illustrated by the following tabulated showing of such elements and their relation to copper in a voltaic cell. This table also shows the alloys resulting from such elements and the copper compounds or alloys formed by the use of such alloys in soldering copper. The electrolyte used for the tests resulting in these tabulated results comprised 3.06% sulphuric acid, 5.85% sodium chloride and the balance water

Relation to Copper in a Voltaic Cell

	Elements						Solders				Compounds		
	Pb	Sn	Sb	Cd	Zn	Bi	Pb Sn	Pb + Cd		Pb Cd Bi Zn	Cu <sub>3</sub> Sn	Cu <sub>2</sub> Sb	Cd <sub>3</sub> Cu <sub>2</sub>
							with Zn	with out Zn					
EP=Electro- positive EN=Electro- negative	EP	EP	EP	EP	EP	EP	EP	EP	EP	EP	EN	EN	EP
A= Anodic C= Cathodic	A	A	A	A	A	A	A	A	A	A	C	C	A
± pole of voltmeter	-	-	-	-	-	-	-	-	-	-	+	+	-
Element destroyed	Pb	Sn	Sb	Cd	Zn	Bi	Sol- der	Sol- der	Sol- der	Sol- der	Cop- per	Cop- per	Cop- per
+ Milli- volts	+560	+460	+300	+600	+710	+220	+280	+850	+470	+900	-50	-100	+500

It will be apparent from this that the nature of the solder alloy applied to copper determines whether such alloy or the copper compound is anodic or cathodic to the copper. For example, when a solder made in accordance with my invention is used upon copper such compounds as Cd<sub>3</sub>Cu<sub>2</sub> result and these are electropositive or anodic to copper. On the other hand, when lead-tin solders are used upon copper, there are certain compounds such as Cu<sub>3</sub>Sn, which are

electronegative or cathodic to copper.

Thus, whenever a solder made in accordance with my invention is applied to copper, the described galvanic corrosion claimed by some to arise from the use of lead-tin solders is avoided with certainty. In any event, my solder is fully effective to prevent "pitting," "pinholing" and "line corrosion" of the soldered surface and the copper adjoining. This is true irrespective of the composition of my copper-cadmium alloy, since the reaction of the alloys or formed compounds is consistently electropositive or anodic to copper in the presence of any electrolyte.

In order to determine the merits of my invention, I have made certain mechanical tests, before and after corroding. Samples of sheet copper were prepared and corroded as follows :

Electrolytic 16 ounce .021 inch thick hot rolled roofing temper copper was used. The samples, three inches by eight inches, were half dipped, giving a solder area of three inches by four inches on each side. A zinc chloride flux was used and applied to the copper at a temperature of 60°C.

Further, another group of samples, after dip soldering, were annealed at a temperature approximating 500°C. for a period of three hours. The purpose of this was to eliminate the possibility of an uneven temperature of heating due to soldering and, what is more important, to demonstrate, even under disadvantageous conditions of soldering at high temperatures, such as 500°C. where disadvantageous electronegative copper-tin compounds are more readily formed, that the compounds and alloys of both which are formed as a result of my invention are consistently electropositive or anodic to copper.

These samples were then subjected to an accelerated weathering or corroding test for 90 hours in a humidor designed for the purpose. The humidor was of the umbrella type, containing a turntable on which the specimens were placed and rotated once every minute. A temperature of 60°C. was maintained and sulphur dioxide gas and carbon dioxide gas were proportionately passed in at a rate to obtain an atmosphere approximating 5% carbon dioxide and 1% sulphur dioxide by volume, the remainder being air and water vapor. The tests made in this apparatus produced a corrosion product on the copper analyzing the same as that naturally produced, thus indicating the validity of the test.

The samples were placed in a vertical plane, the soldered area being at the top to give a hanging drop effect on the solder line. They were removed every 12 hours, sprayed with hot water, dried and returned.

The mechanical tests consisted of an alternate bend test under a tensile load of 4000 pounds per square inch and tensile strength tests were conducted according to standard procedure. As all the mechanical tests were conducted alike, they are, therefore, relative.

The alternate bend test is one which applies to a strip specimen, a direct tension load while it is additionally stressed by being alternately bent or wrapped over a cylindrical surface through an arc of 90 degrees. The test strip is vertically suspended between two 3/4 inch rolls and two bends, one reverse in reference to the other constituting a cycle. The test strip is placed with the mid-boundary (copper solder) just outside the plane of axis of the two cylinders, that is, in the double stressed zone.



The mechanical and corrosion tests are tabulated as follows:

Alternate Bend Tests of Soldered Roofing Copper at Failure

SOLDER	Composition of Solder						Number of Cycles or Double Bends					
							Not Annealed	Annealed				
								Vertically 3 hrs.at 500°C		Horizontally 3 hrs.at 500°C		
	Pb	Cd	Zn	Bi	Sn	Sb	Original	Cor- roded 90 hrs at 60°C	Not Cor- roded	Cor- roded 90 hrs at 60°C	Not Cor- roded	Cor- roded 90 hrs at 60°C
(Copper)							90	74	69	67	50	54
1	85.40	14.23	0.28				84	60	57	45		53
2	82.55	17.45					81	57	50	44		52
3	83.5	6.0	0.5	10.0			83	61	42	45		37
4	100%						72	50	36	33		41
5	50%				50%		77	45	35	26		24
6	95.0				5.0		71	31	37	20		23
7	67.0				24.0		73	49	22	26		19
8	60.0				39.0	1.0	62	45	36	20		19

Alternate Bend Tests And Tensile Tests of Soldered Roofing Copper

	Not Annealed						Annealed											
							Vertically 3 hours @ 500°C						Horizontally 3 hours @ 500°C					
							Original			Corroded 90 hours @ 60°C			Not Corroded			Corroded 90 hours @ 60°C		
	Bend Test Cycles	Tensile Test		Bend Test Cycles	Tensile Test		Bend Test Cycles	Tensile Test		Bend Test Cycles	Tensile Test		Bend Test Cycles	Tensile Test		Bend Test Cycles	Tensile Test	
		Elong. %	U. T. S. lbs./in. <sup>2</sup>		Elong. %	U. T. S. lbs./in. <sup>2</sup>		Elong. %	U. T. S. lbs./in. <sup>2</sup>		Elong. %	U. T. S. lbs./in. <sup>2</sup>		Elong. %	U. T. S. lbs./in. <sup>2</sup>		Elong. %	U. T. S. lbs./in. <sup>2</sup>
(Copper)	90	33	31900	74	34	30500	69	35	30900	67	31	31600	50	32	31800	54	33	30100
1	84	31	32700	60	28	32500	57	30	31400	45	30	30400				53	29	30500
2	81	31	32000	57	31	32900	50	32	31000	44	30	30700				52	24	30500
3	83	32	33000	61	26	33100	42	28	30500	45	28	30800				37	29	30200
4	72	32	32100	50	35	32100	36	31	30400	33	28	29700				41	31	30500
		35	32300	45	23	30800	35	28	31400	26	18	27600				24	17	27200
				31	25	32000	37	27	31100	20		28700				23	23	28300
				49		30800	22	24	30800	26	23	28600				19	22	27700
				45		33200	36	27	31000	20	20	28200				19	21	28400

It will be seen from these tabulated results of the tests made that my solder shows uniform superiority over the lead-tin solders tested.

Another feature of my solder which marks its distinct superiority over cadmium solders arises from the fact that my solder works more readily than those prior art solders having comparatively different percentages of cadmium therein. For example, one of the prior art solders combines  $8\frac{1}{2}\%$  cadmium with  $91\frac{1}{2}\%$  lead. This solder is analogous to a 35% tin 65% lead solder, from the standpoint of workability. On the other hand, my solder containing approximately 14% cadmium,  $1/2\%$  zinc and the balance lead corresponds to a 45-50% tin-lead solder, from the standpoint of workability. It works more easily with a soldering iron than the  $8\frac{1}{2}\%$  cadmium alloy.

My 14% cadmium alloy containing  $1/2\%$  zinc, in addition to the lead, can be used readily either with the application of heat by torches or soldering irons. The prior art  $8\frac{1}{2}\%$  cadmium alloy solder mentioned tends to require the use of torches for application. To illustrate the melting range of other alloys in comparison with my cadmium alloy, I set forth the following table:

<u>Alloy</u>	<u>Complete Liquefaction Point</u>	<u>Solidification Point</u>
8- $1/2\%$ Cd, 91- $1/2\%$ Pb	280°C.	249°C. (estimated)
14% Cd, 86 Pb	258	249 (estimated)
14.2% Cd, .28% Zn, 85.5% Pb	254	238 (determined)
35% Sn, 65% Pb	247	181
47.5% Sn, 52.5% Pb	218	181

In most of the soldering of joints on roofs, the solder is applied by the use of soldering irons. Practical workmen have found that my solder can be applied substantially as readily as a 50-50 lead-tin solder. In the use of soldering irons, if good work is to be done, it is imperative that the soldering irons be kept clean. One of the necessary precautions is to

avoid excessive heat in order to prevent burning or drossing which, of course, makes the iron dirty and prevents good and rapid work.

Thus, it will be seen that I have provided a solder having such electrochemical properties as will obviate all possible danger of "pitting," "pinholing" or "line corrosion" of the soldered surface and adjoining copper that might exist because of improper electrolytic potential. Furthermore, it will be seen that I have provided a solder which, while possessing such electrochemical properties, is at the same time workable with substantially the same facility as the lead-tin solders commonly in use.

Moreover, my solder, when applied to copper for joining or sealing purposes or both, or as a protective coating for the prevention of electrolytic corrosion in the presence of an electrolyte which might result from atmospheric or other conditions, produces a bond that is materially strengthened mechanically and is superior to lead-tin solders used for these purposes. Furthermore, the disadvantageous embrittlement of the alloy regions caused by lead-tin alloys which tends to facilitate mechanical failure of the copper sheet, et cetera, is substantially eliminated by the use of alloys embodying the principles of my invention.

In addition to the aforesaid advantages of my invention, the strength, ductility, hardness, melting point, fluidity and fatigue resistance of the alloys comprising my invention approximate the range of ordinary lead-tin solders employed for similar purposes. Likewise, the small amounts of zinc in the alloys comprising my invention, result in addition to the satisfactory use of the usual hot iron method of sealing joints, in a better surface adherence, materially increasing the

strength of the joint. This is particularly true when employed in a dipping bath for dip soldering. Furthermore, the presence of the zinc acts as a deterrent to oxidation of the cadmium and reduces the danger of oxidation or drossing of the entire alloy.

While I have described my invention as comprising lead alloys containing cadmium with or without zinc, or with bismuth substituted for the cadmium or used therewith, I have nevertheless only set forth specific embodiment of my invention. Consequently, it will be understood that my invention is not limited to alloys specifically set forth in the preceding description but includes the broad idea of forming alloys which either alone or in combination with copper will be electro-positive or anodic to copper and will be applicable thereto with facility equal to the usual lead-tin solders.

Having thus described my invention, what I claim is:

1. An alloy for soldering metal likely to be subjected to an electrolyte comprising elements which are inherently anodic to the metal to be soldered or which form only such compounds with the metal as are similarly anodic.

2. An alloy for soldering copper or its alloys likely to be subjected to an electrolyte comprising elements which are inherently anodic to the metal to be soldered or which form only such compounds with the metal as are similarly anodic.

3. An alloy for soldering copper or its alloys comprising lead and cadmium in substantially the proportions 11% to 18% cadmium and 89% to 82% lead.

4. An alloy for soldering copper comprising an alloy of lead and cadmium substantially in proportions of 14% cadmium and 86% lead.

5. An alloy for soldering copper or its alloys comprising approximately 11% to 18% cadmium, 89% to 82% lead and up to .75% zinc.

6. A solder for copper or its alloys comprising up to .75% zinc, from 11% to 20% cadmium and the balance lead.

7. A solder for copper or its alloys comprising approximately 85.40% lead, approximately 14.30% cadmium, and approximately .30% zinc.

8. A solder for copper or its alloys comprising approximately 82.55% lead, and approximately 17.45% cadmium.

9. A solder for copper or its alloys comprising approximately 83.50% lead, approximately 6% cadmium, approximately 10% bismuth and approximately .50% zinc.

10. A solder alloy for copper or its alloys consisting of lead, bismuth and zinc.